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AIRCRAFT-BORNE MEASUREMENTS OF THE VERTICAL STRUCTURE OF ATMOSP--ETC(U)
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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

AIRCRAFT-BORNE MEASUREMENTS OF THE VERTICAL STRUCTURE OF ATMOSPHERIC AEROSOL IN ACCORDANCE WITH THE PROGRAM FOR THE COMPLEX ENERGY EXPERIMENT

By

V. I. Dmokhovskiy, L. S. Ivlev, V. A. Ivanov

FOREIGN TECHNOLOGY DIVISION

EDITED TRANSLATION

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U. S. BOARD ON GEOGRAPHIC NAMES TRANSLITERATION SYSTEM

Block	Italic	Transliteration	Block	Italic	Transliteration
А а	*А а*	A, a	Р р	*Р р*	R, r
Б б	*Б б*	B, b	С с	*С с*	S, s
В в	*В в*	V, v	Т т	*Т т*	T, t
Г г	*Г г*	G, g	У у	*У у*	U, u
Д д	*Д д*	D, d	Ф ф	*Ф ф*	F, f
Е е	*Е е*	Ye, ye; E, e*	Х х	*Х х*	Kh, kh
Ж ж	*Ж ж*	Zh, zh	Ц ц	*Ц ц*	Ts, ts
З з	*З з*	Z, z	Ч ч	*Ч ч*	Ch, ch
И и	*И и*	I, i	Ш ш	*Ш ш*	Sh, sh
Й й	*Й й*	Y, y	Щ щ	*Щ щ*	Shch, shch
К к	*К к*	K, k	Ъ ъ	*Ъ ъ*	"
Л л	*Л л*	L, l	Ы ы	*Ы ы*	Y, y
М м	*М м*	M, m	Ь ь	*Ь ь*	'
Н н	*Н н*	N, n	Э э	*Э э*	E, e
О о	*О о*	O, o	Ю ю	*Ю ю*	Yu, yu
П п	*П п*	P, p	Я я	*Я я*	Ya, ya

*ye initially, after vowels, and after ъ, ь; e elsewhere.
When written as ё in Russian, transliterate as yё or ё.

RUSSIAN AND ENGLISH TRIGONOMETRIC FUNCTIONS

Russian	English	Russian	English	Russian	English
sin	sin	sh	sinh	arc sh	$\sinh^{-1}$
cos	cos	ch	cosh	arc ch	$\cosh^{-1}$
tg	tan	th	tanh	arc th	$\tanh^{-1}$
ctg	cot	cth	coth	arc cth	$\coth^{-1}$
sec	sec	sch	sech	arc sch	sech^{-1}
cosec	csc	csch	csch	arc csch	csch^{-1}

Russian	English
rot	curl
lg	log

AIRCRAFT-BORNE MEASUREMENTS OF THE VERTICAL STRUCTURE OF ATMOSPHERIC AEROSOL IN ACCORDANCE WITH THE PROGRAM FOR THE COMPLEX ENERGY EXPERIMENT

V. I. Dmokhovskiy, L. S. Ivlev, V. A. Ivanov

In accordance with the program of the Complex Energy Experiment, instruments were installed on an IL-aircraft in 1970 to study the structure of atmospheric aerosol: a photoelectric counter FESA-1 which measures the denumerable concentration of particles with $r \geq 0.2$ μm and the function of particle distribution by sizes (10 fractions); an impactor which permits taking and studying particles with dimensions $r \geq 0.1$ μm; and filtering unit AFU-1 to study the chemical composition of aerosol particles and filtering unit AFU-2 to study the vertical profile of the aerosol and the distribution function of aerosol particles by sizes with $r \geq 0.02$ μm. Measurements were conducted in autumn flights in 1970 using the aircraft-borne impactor and vertical profiles of the denumerable concentration of atmospheric aerosol were obtained with particles $r \geq 0.2$ μm. The spectral density of particle distribution by sizes was also found for various altitudes.

The aircraft-borne impactor which was installed on the IL-18 is a modification of a balloon-borne impactor described in [1]. Problems concerning the effectiveness of deposition in impactors of this type were examined in [1, 2]. However, in connection with the high speed of movement of the instrument which is installed on

the IL-18 aircraft, it is necessary to make a special examination of the question of particle aspiration in the intake device of the aircraft-borne impactor. The theory of this problem was examined in detail in the works of L. M. Levin [3] and S. Badzioch [4, 5].

By the aerosol aspiration coefficient Ω_1 we mean the ratio of the flow concentration of particles averaged for the input cross section of the instrument, $\overline{C}_0$, to the concentration of particles in the undisturbed aerosol C_∞

$$\Omega_1 = \frac{\bar{C}_0}{C_\infty}. \tag{1}$$

The ratio of the mean flow of the concentration of aerosol particles $\overline{C}_0$ which have landed inside the flow to the concentration of particles far from the discharge C_∞ is equal to the ratio of the cross sections of the current tubes formed by the maximum trajectory of the particles and the critical line of the current. For the sampler tube directed exactly toward the laminar flow of aerosol particles with a velocity of the particles of V greater than the rate of aspiration V_S, some particles which would pass by the tube in the absence of inertia enter it, as a result of which the results in determining the concentration of particles prove to be too high; with a rate V_S greater than the velocity of the undisturbed flow U (and particle velocity V), because of inertia some particles do not manage to be deflected into the opening of the tube and the results in determining the particle concentration prove to be too high; with the isokinetic collection of the sample, where $U = V_S$, no distortion of the lines of current occurs and in this case the aspiration coefficient is equal to one.

Let us examine the case where V_S is less than U. If S is the cross section of the intake, then the volume of the gas which reaches the opening will be US and the volume of the gas which is sucked in but does not reach the opening is respectively V_SS and $US - V_SS$. Obviously, all the particles in the volume V_SS land in the tube. A part of the particles from the volume $US - V_SS$ which

is proportional to the α-inertial parameter also lands in the tube. Consequently, the concentration of particles after suction into the intake tube C_S will be

$$C_S = \frac{[V_S SC + (US - V_S S)\alpha C]}{V_S S}, \qquad (2)$$

where $C = C_\infty$, and

$$\Omega_1 = \frac{C_S}{C} = \alpha \frac{U}{V_S} + (1 - \alpha). \qquad (3)$$

Experimental data show [5] that equation (3) is valid when V_S/U is within limits of 0.5-4. The inertial parameter α in work [4] is determined as

$$\alpha = \frac{\left[1 - \exp\frac{L}{\lambda_i}\right]\lambda_i}{L}, \qquad (4)$$

where L - the distance to the nozzle from the place from which the line of current begins to be distorted, λ_i - the inertial path of the particles.

Thus, from formulas (1)-(4) we can estimate the aspiration coefficient for particles of different sizes. For the sampler of the given aircraft impactor Ω_1 will vary depending on the aircraft's speed of movement and the change in the viscosity of the air environment. Calculations of aspiration coefficients which were performed for altitudes of 0-10 km and aircraft speeds (0.9-1.25) x 10^4 cm/s showed that for particles with $r \leq 4$ μm the aspiration coefficient is equal to one with a precision of 5%; it decreases noticeably only for $r \leq 5$ μm (Fig. 1).

Calculations of particle losses due to their deposition in the piping Ω_2 showed that for particles with $r \leq 5$ μm they are no greater than 5%.

The effectiveness of the deposition of particles on the backing Ω_3 was taken as the same as previously. Consequently for $r \leq 5$ μm

the true particle concentration is approximately equal to

$$C = \frac{C_{SS}}{\Omega_3}, \tag{5}$$

where C_{SS} - the concentration of particles which have been deposited on the backing. Correction for background for airplane measurements up to altitudes of 8-10 km is negligibly small in comparison with the concentration of deposited particles.

During the fall measurements in 1970, altogether 19 series of measurements were conducted with the impactor on the IL-18 airplane; however, a large portion of the material proved to be unsuitable for processing due to the unsuitability of the impactor for the rather specific conditions of the experiment - the rapid descent of the aircraft, as a result of which water condensed on the backing and washed away the precipitated particles. In order to exclude this phenomenon in the future, a special plug was designed to close off the impactor during descent and warming of the backing.

Sufficiently desirable results on the aerosol structure were obtained with aircraft measurements on 19 and 25 October.

Measurements were conducted on individual horizontal areas: 300, 1800, 2850, 5550, 8000 m. Figure 2 presents the vertical profiles of the denumerable aerosol concentration for $r \geq 0.2$ μm. The break in the curve of the vertical profile for 19 October is explained by the fact that the aerosol was washed away by precipitation in the interval between measurements at altitudes of 5550 and 2850 m; therefore, the upper part of the curve is a vertical profile of the aerosol before the rain and the lower part of the curve - the vertical profile of the aerosol after the rain. The typical features of these profiles are: 1) a very high denumerable concentration of particles, 2) an exponential decrease in the denumerable concentration with altitude. Typical of the distribution function of the particles by sizes is its relative stability, in which regard the number of particles with $r > 2$ μm is very small.

The particles have primarily an oval shape which permits determining their dimensions rather precisely. Figures 3, 4 present histograms of particle distribution by sizes.

It is interesting to note that the washing away of the aerosols by precipitation on 19 October had a substantial effect on the particle size distribution function for $r \geq 2$ μm and $r \leq 0.3$ μm. Tables 1-2 present the numerical results of aircraft measurements on 19 and 25 October 1970.

Earlier, the authors had already conducted measurements of the aerosol structure using a LI-2 aircraft in the Caspian area. The values of the denumerable concentration obtained there are 3-5 times less and, in addition, a layered structure of the aerosol and instability of the particle size distribution function were observed. Such a divergence in the results can be explained, probably, by the different nature of the aerosol, the almost complete absence of hygroscopic particles in the aerosols above Karakumy, and the strong intermixing of aerosol in the atmosphere above the desert.

Let us formulate the basic conclusions briefly.

1. The employment of a balloon-borne impactor with some changes in the design for measurements from an airplane is possible.

2. The range of particle dimensions measured using the aircraft impactor, 0.1 μm $< r \leq 4$ μm.

3. The vertical course of the denumerable aerosol concentration in the autumn above Karakumy is an exponential decrease in the concentration with altitude in which regard the values of the denumerable concentration are very high, exceeding by 3-5 times the values of concentrations above other regions of the USSR at the same time.

4. The stability of the aerosol particle distribution function for sizes at various altitudes, which can be described approximately by the Junge formula with ν = 3-3.5, is sufficiently high.

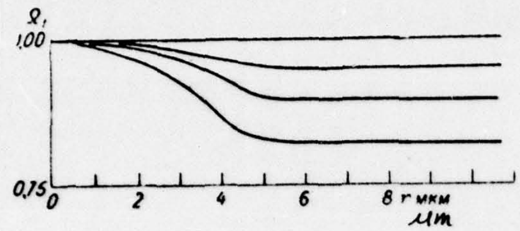

Fig. 1. Aspiration coefficients of particles for aircraft speeds $(0.9-1.25)\cdot 10^4$ cm/s.

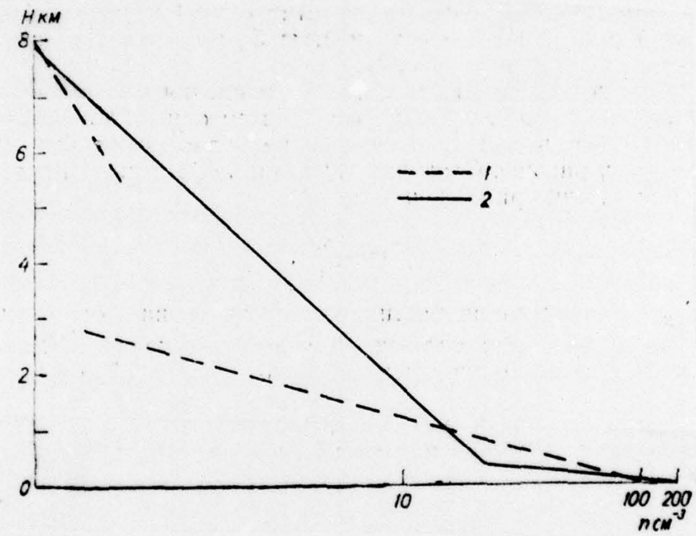

Fig. 2. Vertical profiles of denumerable aerosol concentration n for 19 September (1) and 25 October (2).

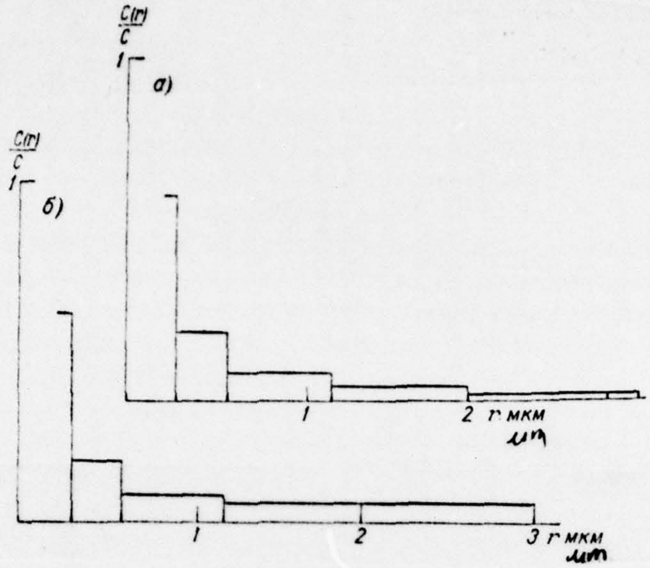

Fig. 3. Histogram of the particle size distribution for 19 October at altitudes of 5550 m (a) and 8400 m (b).

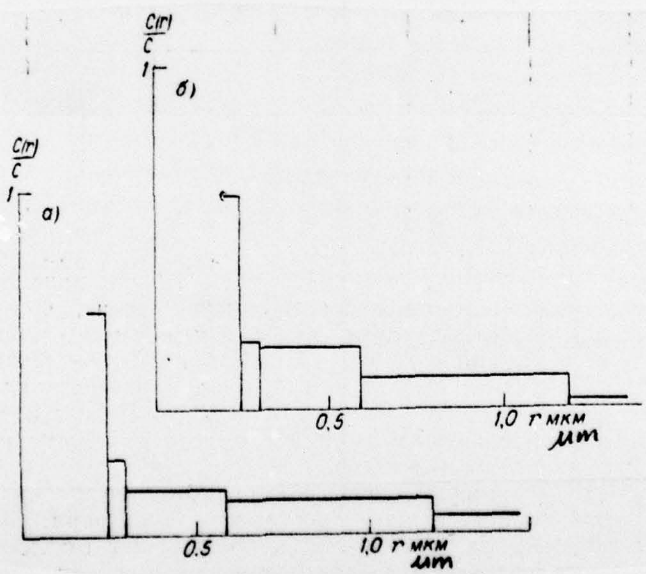

Fig. 4. Histogram of particle size distribution for 25 October at altitudes of 5500 m (a) and 8000 m (b).

Table 1. Particle size distribution [C(r)/C] for 19 October 1970 (night flight).

H м	C см$^{-3}$	r мкм μm					
		<0,25	0,25–0,30	0,30–0,6	0,6–1,2	1,2–2	2–3
0	115	0,71	0,21	0,04	0,03	0,01	—
1300	11	0,60	0,25	0,09	0,04	—	—
2850	2	—	0,65	0,25	0,08	0,02	—
5550	3	—	0,60	0,20	0,14	0,04	0,01
8400	0,1	—	0,61	0,18	0,08	0,06	0,06

Table 2. Particle size distribution [C(r)/C] for 25 October 1970 (day flight).

H м	C см$^{-3}$	r мкм μm				
		< 0,25	0,25–0,30	0,30–0,6	0,6–1,2	>1,2
0	200	0,70	0,14	0,08	0,045	0,035
300	43	0,63	0,19	0,17	0,023	0,04
1300	18	0,60	0,24	0,14	0,014	0,02
2850	5	0,57	0,09	0,16	0,010	0,01
5500	1	0,65	0,22	0,13	0,010	0,005
8000	0,5	0,62	0,19	0,18	0,009	0,002

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